Abstract

In many practical situations, a combination of normal as well as shear tractions can exist on the plane ahead of a crack tip, resulting in mixed-mode loading Some examples are loading asymmetry with respect to the crack line, presence of constraints such as a weld or fillet on the crack line and propagation of cracks at bi-material interfaces The objective of this thesis is to study the stress and deformation fields near a quasi-statically propagating crack tip in an elastic-plastic solid under mixed-mode loading (involving Modes I and II) To this end, a special finite element procedure based on moving crack tip coordinates is employed to simulate steady-state crack growth under plane strain, small scale yielding conditions The material is assumed to obey the J_2 flow theory of plasticity with power-law hardening

The work reported in this thesis is conducted in three parts First, steady crack growth subjected to remote K-based loading is simulated in homogeneous elastic-plastic solids The near-tip field quantities are studied in great detail corresponding to various levels of remote elastic mixity, $\psi^e = tan^{-1}(K_{II}/K_I)$ where K_I and K_{II} are Mode I and II stress intensity factors respectively The near-tip plastic mixity is measured in terms of an angle $\psi^p = tan^{-1}(\sigma_{12}/\sigma_{22})$, where σ_{12}/σ_{22} is the ratio of shear traction to the normal traction on the plane ahead of the tip The near-tip mixity ψ^P is found to depend on the remote elastic mixity ψ^e as well as on the level of strain hardening It is observed that that for remote elastic mixity ψ^e in the range of 0^o to 60^o, a Mode-I type field with ψ^p close to 0^o is approached near the crack tip Thus, the near-tip stress distribution obtained for very low strain hardening matches well with that available for Mode I crack growth perfectly-plastic solids On the other hand a near-tip Mode II type field with ψ^p of 90^o is obtained only for ψ^e very close to 90^o. The results indicate the existence of near-tip mixed-mode fields at physically relevant length scales from the growing crack tip for remote mixity ψ^e between 60^o and 90^o.

In the second part, the elastic T-stress, which is the second (non-singular) term of the William's asymptotic expansion is included along with the K-field in the remote boundary conditions. Thus, a modified small scale yielding problem is modelled corresponding to different values of ψ^e and T/σ_o, where σ_o is the yield stress of the material. The results indicate a strong dependence of the near-tip mixity on the applied T-stress. An application of remote positive T-stress gives rise to a near-tip stress distribution which resembles the pure Mode I field for all remote mixities ψ^e in the range from 0^o to 90^o. An application of remote negative T-stress gives rise to a near-tip mixity ψ^p of 0^o for ψ^e in the range from 0^o to 60^o. A value of ψ^p of 90^o is attained for ψ^e between 82.5^o and 87.5^o. For ψ^e greater than 87.5^o, a compressive normal stress prevails on the plane ahead of the tip resulting in $\psi^p > 90^o$.

In the final part of the thesis, analytical asymptotic solutions are obtained for plane strain mixed-mode quasi-static crack growth along a ductile-rigid interface. The ductile material is taken to be elastically compressible and to behave in an ideally plastic manner. Two families of solutions displaying a range of near-tip mixities are obtained. One family is characterized by high stress triaxiality and is called a tensile-type solution. The other family is characterized by low triaxiality and is a shear-type solution. The angular distribution of stresses around the crack tip depends significantly on the near-tip plastic mixity.